

*San Joaquin watershed.*—The river stages of this watershed averaged much above the normal for the month, and all streams carried more water than for any April since that of 1907.

#### FROST FIGHTING IN CALIFORNIA VINEYARDS.

By W. E. BONNETT, Local Forecaster.

On April 13 this section was visited by one of the most damaging frosts that has occurred here for many years. Reports as to the aggregate damage are necessarily somewhat conflicting, and its extent will probably not be definitely known for many weeks, but the injury to raisin and wine grapes is likely to be between 40 and 50 per cent of an average crop. As is the case with most fruits, many varieties of vines do not recover when the first tender shoots have been frozen, and the crop for the season is lost. However, a few varieties do put forth new fruit buds after the first growth has been killed and these produce a somewhat later and lighter yield. This circumstance makes early estimates of the ultimate damage more uncertain.

A review of the meteorological conditions leading up to this frost may be interesting. High barometric pressure over the North Pacific States and persistent low pressure over southern California and Arizona resulted in desiccating northerly winds during the 11th and 12th. A damaging frost on the former date was prevented only by the considerable wind movement which continued during the night. At 5 p. m. of the 11th the dewpoint was 30° and the relative humidity 34 per cent. At 5 p. m. of the 12th, after another 24 hours of dry northerly winds, the dewpoint was 16° and the relative humidity 18 per cent. On but one other occasion in our record of April frosts has the atmospheric moisture been so low, on April 4, 1895, and this was followed by a killing frost next morning. Owing to the extreme dryness of the air there was very little actual frost, absolutely none where the damage was severe, and the resulting phenomenon was what is often popularly spoken of as a "black frost," a name for the effect rather than the name of the phenomenon itself.

Warnings of a severe frost had been issued on the morning of the 12th, and upon the kind invitation of Mr. George C. Roeding, a prominent nurseryman and fruit grower, I spent the night of the 12th and 13th at his country home, about 8 miles east of Fresno, to witness an experiment in frost fighting. He had provided fire pots and materials for firing in 30 acres of a 130-acre vineyard of Thompson Seedless grapes, and his experiment is probably the first systematic attempt at frost fighting in the vineyards of this locality. The results were pleasing to him, and they will be generally instructive to grape growers.

No opportunity was offered for securing the instruments necessary to a proper history of the experiment; we had no thermograph and not enough thermometers, but the thermometers we had, all belonging to Mr. Roeding, had been compared with the instruments in the local office of the Weather Bureau, and I can personally vouch for their accuracy. Upon arising at 2 a. m. it was found that the temperature had fallen to 32° and the fires were lighted as quickly as possible. Thirty fire pots to the acre were used, and they were charged to about one-half of their capacity with 8 pounds of a specially prepared fuel of sawdust and shavings, saturated with crude oil. Soon after 3 o'clock all fires had been lighted. Two thermometers were placed in different parts of the vine-

yard on the trellis and about 3 feet above the ground; one was placed to the west, the windward side, another about 50 yards south from the vineyard. A minimum thermometer was left at the ranch office, perhaps one-eighth of a mile from the fires. An examination of this instrument at 5 o'clock showed a minimum of 27°. From 3.30, when the effects of the firing were becoming apparent, until 6 a. m., the temperature in the vineyard fluctuated between 32° and 35°. The temperatures shown by thermometers outside of but quite near to the vineyard ranged between 29° and 31° during the same time, but I believe they were too close to the vineyard to give the minimum that would have been reached in undisturbed air. The heat from the fires induced a gentle indraft of air toward the vineyard, and this caused sufficient mixing near its borders to prevent the occurrence of a minimum as low as that shown by the thermometer entirely removed from any effect of the heating.

Now, it will be observed that the increase in temperature produced by this firing was not great, but the vineyard shows no injury while near-by vineyards similarly located suffered serious damage. This emphasizes the fact that the thermal margin between freezing and nonfreezing was very small. The fact that this difference is very small, a difference that should be overcome with comparative ease by smudging or firing, is further emphasized by many peculiarities in the distribution of the damage. It is found that the frost, although fairly general, has wrought injury in its customary freaky fashion. It may be pointed out that the major portion of the grapes here are grown on a practically level plain many miles from the foothills, most of them from 10 to 30 miles and more, and that the differences in elevation within short distances, say for example, from vineyard to vineyard, are quite small. However, these small differences in elevation have meant in many cases the difference between injury and immunity; in other cases the vineyards into which the irrigation waters had been turned were saved; in still other cases recent cultivation or the lack of it seems to have made a difference in the extent of damage. All of this shows that the danger lies within very narrow temperature limits.

It is not often that frosts occur which are generally damaging to the grapes of this locality, and the preparations for an annual warfare against it, so necessary in less-favored sections, are not required here, but a series of favorable seasons begets a feeling of security on the part of the growers and the protective measures that might be easily applied are not used.

The absolute minimum for April at this station is 34°, and this has been reached in 6 Aprils of the last 24, but damaging frosts occurred on but two or three of these occasions. The low temperatures of the remaining occasions came in conjunction with other conditions of wind, weather, or moisture which prevented frost. It should be pointed out that this record is from a roof exposure of thermometers that has varied from 36 to 67 feet above the ground since the establishment of the station. On the occasion under discussion reliable instruments exposed near the ground in various places in the vicinity of Fresno recorded minimum temperatures of 27° and 28° as against our 34°, and on a quiet night 6° probably represents the amount of temperature inversion at the elevation of our instruments.

The temperature conditions prevailing on the morning of the 13th were probably as extreme as ever occur here in April, and they should be easily overcome at small cost of labor and materials for smudging or heating. In the

experiment cited, 30 fire pots per acre sufficed. For more extreme conditions in orchards elsewhere I find that 80 or 100 per acre are recommended. It should also be understood that vines are pruned very low, they being from 2 feet to 4 feet high, depending on whether or not they are staked or trellised, and there is thus no tree crown to entrap the heat from fires. But even with this disadvantage complete protection seems easy and sure, and many growers are awakening to the fact.

#### FROST CARTRIDGES.

By Prof. ALEXANDER G. MCADIE.

It seems advisable to publish the following as a preliminary note in connection with experiments made at San Francisco on the protection of tree fruits from injury by frost.

It has been pointed out in previous papers published in the Monthly Weather Review, that while orchard heaters of the type now in general use served a good purpose, and if used in sufficiently large numbers would afford protection in orchards, there was one serious objection to their use, namely, that the heat could not be applied at the particular level where most needed and therefore the highest efficiency was not obtained. Just as the orchard heaters marked a distinct advance over the old-style open fires, which warmed up all out of doors, so it is thought a proper use of antifrost candles, or cartridges, as they have been called from a fancied resem-

blance to a large cartridge, will be a decided improvement upon the use of heaters placed on the ground.

The cartridge consists of a cylindrical tube of heavy cardboard or other suitable slow-burning material, which is filled with a mixture of crude oil, gravel, and sawdust. Two stoppers are provided to close the ends of the tube. When filled the cartridge is suspended by a wire about 3 feet below the fruit in a horizontal direction. When used the stoppers are removed and a torch applied to small amounts of cotton waste, which have been soaked in kerosene and placed at the ends of the cartridge. A cartridge case 2 feet long and 1½ inches in diameter will burn about 2 hours. If the combustion is good there will be nothing left but the gravel and a small residue of charred cardboard.

The tubes may be filled with the mixture during the afternoon hours. Tests made at San Francisco show that the tubes will hold the oil without leakage and also without softening for several days. There will be, however, a discoloration after 24 hours. The tubes are easily handled and are comparatively cheap.

There are two objections to the use of this method, however, first, the danger of fire from the burning ends, and second, the large amount of soot given off, a portion of which is deposited upon the fruit. Experiments are in progress looking toward the atomization of the crude oil, so that the combustion will be improved.

Some form of metallic screen to be placed above the cartridge would be a great improvement, but this would materially add to the expense.